# General Disclaimer

## One or more of the Following Statements may affect this Document

# Thermal Expansion of Hafnium Carbide

## by SALVATORE J. GRISAFFE

SINCE hafnium carbide (HfC) has a melting point of 7029°F.,[1] it may have many high-temperature applications. A literature search uncovered very little information about the properties of HfC, and so a program was initiated at the Lewis Research Center to determine some of the physical properties of this material. This note presents the results of the thermal-expansion investigation.

The thermal-expansion measurements were made with a Gaertner dilatation interferometer calibrated to an accuracy of ±1°F. This device indicates expansion by the movement of fringes produced by the cancellation and reinforcement of fixed wave-length light rays which are reflected from the surfaces of two parallel quartz glass disks. The test specimens which separate these disks are three small cones, each approximately 0.20 in. high.

The sets of cones used in test I and test II were diamond ground from hot-pressed HfC pellets.[2] The set used in test III was diamond ground from a 4- by $^1/_2$- by $^1/_4$-in. hot-pressed HfC bar. Based on a theoretical density of 12.1 gm. per ml.,[2] the per cent theoretical densities for the cones used in each test were as follows: test I, 97.5% (11.8 gm. per ml.), test II, 99.2% (12.0 gm. per ml.), test III, 96.2% (11.6 gm. per ml.).

The chemical analysis (weight %) for the −325-mesh HfC powder (average particle size, 3.04 $\mu$) from which the hot-pressed specimens were made was as follows: Hf 89.36, combined carbon 6.06, free carbon 0.03, Zr 3.45, Ti 0.39, B 0.72, total other metal impurities 0.05.

The theoretical density for this material was calculated from this analysis and a unit-cell dimension of 4.63 a.u. (determined by X-ray diffraction assuming a NaCl-type structure).[2] Zirconium and titanium atoms were assumed to take hafnium atom positions whereas boron atoms were assumed to take unfilled carbon atom positions.[2]

Each run involved heating the test cones at about 8°F. per minute to the desired test temperature and then cooling at the same rate. The results are shown in Figs. 1 and 2. Each point was computed from the number of fringes moved and this expansion was corrected for the variation of the index of refraction of air.[3] One point could have been shown for each fringe which was counted, but this would have made the differentiation of the tests very difficult. Therefore, only a representative portion of the points is shown. All these data are correct to three significant figures.

Figure 1 shows the results of the initial testing of each of the three sets of HfC cones. Figure 2 shows the results of repeat tests on the cones used in tests I and II (tests I–A and II–A). In the second figure, a slight deviation can be seen in the decreasing-temperature portion of test I–A. This deviation was caused by a long holding time at the highest temperature. The cones used in tests I and I–A had very acute apex angles. The weight of the quartz glass disk pressing down on three points caused a very shallow penetration of the disk by the cone tops. This penetration resulted in a slight shifting of the expansion curve. Test I was not held at high temperatures and so this penetration did not occur. The rest of the runs were made with cones whose apices had been blunted.
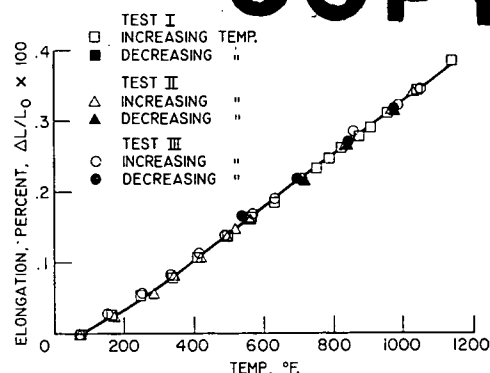


Fig. 1. Effect of temperature on elongation of hafnium carbide.
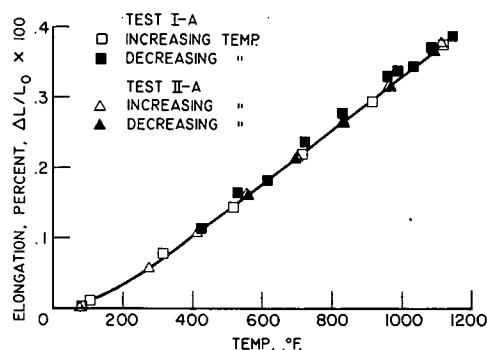


Fig. 2. Effect of temperature on elongation of hafnium carbide in repeat tests on specimens used for data in Fig. 1.

Owing to the excellent correlation of all five tests, density variation, in the high-density range, appears to have no effect on the thermal expansion of hafnium carbide. A coefficient of thermal expansion was calculated from the foregoing data, as follows: $\alpha$ HfC = 3.66 ± 0.02 × $10^{-6}$ per °F. from 77° to 1133°F. or 6.59 ± 0.04 × $10^{-6}$ per °C. from 25° to 612°C.

The writer is materials research engineer, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio.

[1] I. E. Campbell (Editor), High Temperature Technology, p. 114. John Wiley & Sons, Inc., New York, 1956. 526 pp.
[2] W. A. Sanders and S. J. Grisaffe, "Hot Pressing of Hafnium Carbide, M. P. 7030°F.," NASA Technical Note D-303, 1960.
[3] G. E. Merritt, "Interference Method of Measuring Thermal Expansion," Bur. Standards J. Research, 10 [1] 59–76 (1933); RP 515; Ceram. Abstr., 12 [3] 129 (1933).